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TITLE OF THE INVENTION

Operational Process for a Data Bus for a Plurality of Nodes

This application claims the priority of German Patent Document 198 10 293.3 filed March 10, 1998 and PCT/EP99/01163 filed February 23, 1999, the disclosures of which are expressly incorporated by reference herein.

BACKGROUND AND SUMMARY OF INVENTION

The invention relates to an operational process for a data bus for a plurality of nodes as follows from the German Patent Application 19720401.5 not previously published. Each message possesses an unambiguous identifier which determines the urgency of the message.

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~~The data bus includes, for at least some of the nodes, optical transmission segments. The messages are converted into electric signals and converted via a receiver/transmitter unit once again into a preferably optical signal telegram which is thus transmitted to all the remaining nodes. A data bus of this type with at least one partially optical transmission segment include a particular characteristic the signal transit time, that is, the time for the transmission of a signal from one node to another is significantly greater than the bit time. In contradistinction thereto the signal transit time in the case of a purely electrical data bus, as, for example, is frequently used in vehicles under the designation CAN, is significantly smaller than the bit time. An additional~~

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~~difficulty due to the sharply differing signal transit times~~ arises when additional nodes are connected to the data bus which themselves output (only) electrical signals.

An example, is represented in Figure 1, which has a star-shaped bus system with four nodes T1 to T4 in which nodes T1, T2, and T3 are connected via an optical transmission segment L1, L2, and L3 to an active electric star coupler K. Between each of the nodes T1 and T3 and the star coupler K two SE (transmitter/receiver) units SE_{11}, SE_{12}, SE_{21}, SE_{22}, SE_{31}, and SE_{32} are disposed in which the electrical signal present originally at the nodes is converted into an optical signal and is reconverted into an electrical signal which then is given to the star coupler K. In reverse, the optical telegrams intended for the nodes starting originally from the star coupler are converted into optical telegrams and then, in turn, into electrical receiver signals.

Furthermore, an additional node T4 is disposed which is connected via an electrical transmission segment directly to the star coupler K.

Depending on the conversion time from the electrical into optical signals and vice versa (about on the order of magnitude of 60 - 100 ns each) and the transit time in the optical transmission segments (ca. 5 ns/m), transit times for information from each of the nodes T1 to T3 to and from the star coupler K , for example, in the exemplary embodiment 180,

240, and 200 ns. The transit time of the signals from node T4 to the star coupler K is ideally equal to 0 ns.

If one assumes, for example, information signals which are from node T1 to node T2 via the star coupler K, then a transit time of at least 420 ns results, for information signals from node T3 to T2 of 440 ns. The minimal signal transit time for signals between the nodes T1 and T4 is 180 ns.

It can be seen without further effort that the transit time in the system depends strongly on the respective individual delay times in the transmission segments of the individual nodes to the active star coupler and moreover is significantly greater than the bit time, here, for example, assumed equal to 100 ns.

Let us now assume signal traffic on the data bus as follows from Figure 2. Between two synchronization pulses which are output by a bus master, a data transaction takes place on the data bus. In each of the cycles designated as cycle 1, cycle 2, and cycle 3 at most three signals are output which are the signals t1, t2, and t3 or t1, t4 and t5 or the signal t3 alone. Between each of the actually transmitted signals, there is at least one delay time which follows from the following equation.

Wait time: $t\ wx = t\ wx0 + t\ wx\ delta * (ID - ID_{x-1})$

Therein t_wx0 means a fixed percentage which serves to unambiguously distinguish signal and wait time, t_wx_delta a fixed multiplication percentage which depends on the maximal signal transit time in the bus system, and ID – ID_{x-1} the difference of the signal identifier. Therein ID stands for the identifier of the signal to be actually sent by the node and ID_{x-1} for the identifier of the last signal actually transmitted.

As can be easily seen, the distance is minimal between two transmitted signals, and with regard to their identifier, sequential signals, (e.g., between the signals t1 and t2 or t2 and t3 as well as between t4 and t5). However, for signals not directly sequential with regard to their identifier, such as t4 after t1 in cycle 2, the distance is greater.

The calculation of the multiplication percentage t_wx_delta following from the transit times can be explained with the aid of Figure 3.

If two nodes are assumed, designated as A and B, then Node B transmits a signal with ID = 1 and node A a signal with ID = 2. Furthermore, if node A be is assumed as bus master then Node A. transmits the synchronization pulse and starts, after the end of the synchronization pulse, the wait time t_wx. Node B sees the end of the synchronization pulse but delayed by t_max and thus starts its wait time t_wx t_max later. Node B begins after the expiration of the wait time

t wx = t wx0 = t wx delta*1

with the transmission of the signal ID = 1. This signal in turn needs t_max in order to arrive at node A. Node A must still be able to receive this signal before it, begins with the transmission of the signal ID = 2. The following equations must therefore be satisfied from the standpoint of node A in order to avoid a collision.

Start time telegram ID = 2 > Receiving time telegram ID =1

t wx0 + 2*t wx delta > t max + t wx delta + t max

From this it follows:

t wx delta > 2*t max

In the case of the exemplary configuration, t_wx_delta=880ns thus follows from Figure 1. In case of large identifier differences, for examples (ID - ID_{x-1}) = 250 a wait time of over 220 μs thus results. This means that in the case of a required cycle time of, for example, 200 μs, signals with high identifiers, cannot be transmitted at all. Furthermore, the net data throughput also decreases with the use of small IDs with t_wx_delta becoming greater.

The objective of the invention is to provide an operational process for a data bus for a plurality of nodes in which the degree of efficiency is increased by reducing the wait time between the signals to be transmitted.

This solution consists of adjusting the transit times delays, in particular between the nodes and the active star coupler. In the ideal case, this adjustment should be performed to the extent that the signal transit times between the nodes and the star coupler are equal. The measures according to the invention consist of adapting the fixed percentage of the wait time t_wx0 individually.

The invention is implemented by various measures which can be applied jointly or alternatively. These measures are explained with the aid of the additional figures.

Other objects, advantages and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an illustration of a star-shaped bus system having four nodes;

Figure 2 illustrates an example of data traffic on the data bus of Figure 1;

Figure 3 is an illustration of the calculation of the multiplication factor t wx delta;

Figure 4 is a diagram showing the setting of the delay as a function of the last bus activity;

and

Figure 5 is a diagram illustrating the synchronization of the nodes by adjusting each node wait time according to a transmit time between the node and the star coupler .

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in Figure 4, the nodes distinguish the transmitting and receiving case for the last bus activity. The node which has transmitted the last bus activity (sync pulse or signal) waits t_min longer than the other nodes which have received this bus activity. In place of the universal fixed percentage t_wx0 a fixed percentage t_wx0_tx for the transmitting case or t_wx0_rx for the receiving case now appears.

t wx0 tx = t wx0 rx + t min is for transmitting case

t wx0 rx   is for the receiving case

The following wait time must be satisfied from the view of node A in order to avoid a collision.

Start time telegram ID = 2 > Receiving time telegram ID =1

t wx0 rx + t min + 2*t wx delta > t max + t wx0 + t wx delta + t max

For this it follows:

t wx delta > 2*t max-t min

Thereby the value of t_wx_delta can be reduced from 880 ns to 700 ns in the exemplary configuration of Figure 1.

In addition or alternatively,, the fixed percentage of the wait times t_wx0_tx and t_wx0_rx for each node can be adapted to its individual delay time (here called delay_tln). This happens according to the following formulas.

- t wx0 tx tln = (idle min - t wx delta) tin max + delay tin
- t wx0 rx tln = (idle min - t wx delta) tin max + delay tin

The parameters used herein have the following meaning.

Table 1

Parameter:	Meaning:	Example:
delay tin	Maximal delay of a signal from the electrical part of the star coupler to the node tln in the worst case	delay_μP, delay_μC1, delay_μ2
delay tin max	Maximum (delay_tln_1, delay_tln_2, . . .)	Here: delay_tln_max = 240 ns
idle min	Minimal "Bus Idle" time between telegrams	1100 ns
t wx delta	Multiplicative factor of the wait time	In the ideal case: t_max

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~~If these equations are applied to the bus configuration of Figure 1, then the parameters follow as entered in Figure 5 for the individual nodes. In Figure 5 the signal curves are furthermore shown which the individual nodes see at their bus connection.~~

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~~It can be seen from Figure 5 that, by the adaptation of the~~ fixed percentage of the wait time t_wx0_tx and t_wx0_rx, the nodes are synchronized. The start time of a SIGNAL then no longer depends on the different signal transit times in the system (from optical and in a given case electrical transmission segments from and to the star coupler) but rather only on the identifier of the signal to be transmitted and the allocation of the data bus by a (more important) with lower identifier. If the nodes would all transmit one and the same telegram with an identical identifier, they would do this simultaneously. Since only one node transmits each telegram ~~with a certain identifier, a collision of signals is avoided.~~

Thus the following now applies.

t wx delta>/=t max

Thereby a halving of the multiplicative percentage of the wait time t_wx_delta is achieved. In the exemplary configuration of Figure 1 this means for t_wx_delta a value of 440 ns with respect to 880 ns. High identifiers, for example, ID = 250 have a wait time of ca. t_wx = 110 μs and therefore can still be transmitted within a cycle of 200 μs.

Since in the normal bus operation many different and, thus, also higher identifiers are used, only rarely are directly sequential identifiers transmitted within one frame. Thus the halving of t_wx_delta causes approximately a halving of the wait times t_wx. This has, in turn, the effect of nearly

doubling the net rate of data throughput.. Overall, therefore, the degree of efficiency of the protocol is increased. In the case of a fixed net data rate, the gross rate of data throughput can thus be lowered. Thereby cost reductions are possible due to the lower frequency of signals. The EMC protection can be structured more simply with such stringent requirements for the structural parts.

For the realization of the invention, adaptation and logic elements not represented are provided in the nodes which perform the specified adjustments of the starting time points for the signal as a function of the immediately preceding activity (transmitting or receiving) of the node itself and the individual signal transit time between the node and the star coupler. Because significant transit time differences between nodes with electrical connection and the nodes with optical connection are present, it is sufficient to approximately compensate these transit time differences by delaying the transmission of only the node with electrical connection by a time span which is approximately equal to the average delay time of the node of the other type (with optical connection). A sufficiently short time value follows, for example 210 ns.

The foregoing disclosure has been set forth merely to illustrate the invention and is not intended to be limiting. Since modifications of the disclosed embodiments incorporating the spirit and substance of the invention may occur to persons

skilled in the art, the invention should be construed to include everything within the scope of the appended claims and equivalents thereof.